

# Selenium in the Environment

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September 2004

# Outline of Presentation

- ⌘ **General selenium information**
- ⌘ **Fate and transport**
- ⌘ **Bioaccumulation**
- ⌘ **Chronic and acute toxicity levels**
- ⌘ **Action levels/levels of concern**
- ⌘ **Health advisory for Salton Sea**
- ⌘ **Impacts of selenium to wildlife at other sites**
- ⌘ **Selenium at Salton Sea**

# General Selenium Information

- ⌘ **Occurs naturally in rocks and soils**

- ⌘ **Multiple oxidation states**

  - ☐ selenide ( $\text{Se}^{2-}$ ), elemental selenium ( $\text{Se}^0$ ), selenite ( $\text{Se}^{4+}$ ), and selenate ( $\text{Se}^{6+}$ )

- ⌘ **Form varies depending on conditions (such as pH, oxidation/reduction state, and microbial activity)**

- ⌘ **Can cause severe reproductive effects in fish and wildlife**

# Selenium Can't Be Ignored

**A** Gadwall (Kesterson Reservoir, California) with arrested development of lower bill, spoonbill narrowing of upper bill, and missing eyes



**B** Northern Pintail (Tulare Lake Bed area, California) with arrested development of lower bill, spoonbill narrowing of upper bill, and missing eyes



**C** Redhead (middle Green River Basin, Utah) with spoonbill narrowing of upper bill



**E** Black-necked stilt (Kesterson Reservoir, California) with missing eyes, malformed bill, limb deformities and exencephaly



# Fate and Transport

## ⌘ Water

- ☒ In alkaline waters, soluble selenate salts predominate.
- ☒ Selenates are highly mobile due to their high solubility and low adsorption onto soil particles.
- ☒ Selenites are less soluble in water than the corresponding selenates.
- ☒ Organic selenium is typically less abundant than inorganic selenium (selenate and selenite) but toxicologically important.

# Fate and Transport (cont.)

## ⌘ Plants

- ☑ Selenate is the preferred form for uptake.
- ☑ In acidic soils with high moisture, selenite (the predominant form) is not bioavailable to plants.
- ☑ In basic soils, soluble selenates are responsible for the naturally occurring accumulation of high levels of selenium by plants.
- ☑ Overall, selenium occurs in both plant and animal tissues, but bioavailability is greater from plant selenium than from animal foods.

# Fate and Transport (cont.)

## ⌘ Aquatic Systems

- ☒ Selenium is generally associated with sediments (acting as a sink and reservoir) or plants and animals.
- ☒ Relatively small amounts are found dissolved in water.
- ☒ In bottom sediments, metal and organic selenides are most common.

# Bioaccumulation

## ⌘ **Selenium bioaccumulates in both aquatic and terrestrial food chains**

- ☒ Water to aquatic plants or invertebrates serves as the greatest “step” in bioaccumulation (often 1000X waterborne concentration).
- ☒ Bioaccumulation from water depends on chemical form (organic>selenite>selenate).
- ☒ Ingestion is the main uptake pathway in the aquatic or terrestrial system because concentrations in water or air are usually low.



# Chronic and Acute Toxicity

## ⌘ Wildlife

- ☒ At increased dietary levels, selenium replaces sulfur in some metabolic pathways.
- ☒ Toxicity can occur when dietary selenium concentrations are about 5 mg/kg (2-3X background).
- ☒ Chronic selenium toxicosis causes reproductive problems (embryo mortality and teratogenesis) in birds.
- ☒ Early life stages of birds are most sensitive.

# Chronic and Acute Toxicity (cont.)

## ⌘ Aquatic Biota

- ☒ When water is the only exposure route, selenium is not very toxic to fish or wildlife.
- ☒ However, eggs and larvae of fish and amphibians are sensitive to waterborne selenium.
- ☒ Eggs of fish and birds and larvae of fish are sensitive to the lethal or teratogenic effects of selenium transferred to the eggs by the female parent.

# Action Levels/Levels of Concern

- ⌘ **Field and laboratory studies suggest threshold levels and levels of concern.**
- ⌘ **A chronic dietary concentration of 2 mg/kg has been suggested as a maximum tolerable level for all species.**
- ⌘ **For aquatic life, the USEPA criterion is 5  $\mu\text{g/L}$ ; proposed revisions of criteria are expected soon.**

# Action Levels/Levels of Concern (cont.)

## ⌘ Fish

- ☒ Levels of concern range from 2-3 mg/kg in diet and 1-2  $\mu\text{g/L}$  in water.
- ☒ Levels of concern in whole bodies of fish range from 2-4 mg/kg.

## ⌘ Aquatic Birds

- ☒ Levels of concern/effect thresholds range from 3-6 mg/kg in bird eggs, 3-8 mg/kg in diet, and 1-3  $\mu\text{g/L}$  in water.
- ☒ Concentrations of 5-20 mg/kg in diet may load eggs above teratogenic thresholds.

# Action Levels/Levels of Concern (cont.)

## ⌘ Humans

### ☑ Recommended Daily Allowance

☒ Ranges from 0.015 to 0.7 mg/day

- 55 kg adult- 0.0002 to 0.013 mg/kg/day

☑ Over a lifetime, an oral exposure of 0.023 mg/kg/day (LOAEL) to organic selenium caused selenosis in a female while a dose of 0.015 mg/kg/day had no observed adverse effect.

☑ Health advisories generally are based on concentrations of 2 mg/kg (wet weight) in fish, etc.

# Health Advisory for Salton Sea

⌘ “Because of elevated selenium levels, no one should eat more than four ounces of croaker, orangemouth corvina, sargo, or tilapia taken from the Salton Sea in any two-week period. Women who are pregnant or may become pregnant, nursing mothers, and children age 15 and under should not eat fish from this area.”

# Health Advisory for Salton Sea (cont.)

## ⌘ **Basis of Advisory:**

- ☑ 2 ppm wet weight selenium screening level, first applied to waterfowl at Kesterson Reservoir.
- ☑ Screening level has been applied at other sites, such as Salton Sea and San Francisco Bay.

# Selenium at Other Sites

## ⌘ Kesterson Reservoir

- ☒ Selenium caused high rates of embryo mortality and deformities, plus death of adult aquatic birds.

## ⌘ Tulare Basin

- ☒ Selenium caused embryonic mortality and deformities in aquatic birds.

## ⌘ Green River Basin

- ☒ In Wyoming, Colorado and Utah, elevated selenium concentrations inhibit reproduction in razorback suckers and impact aquatic birds.

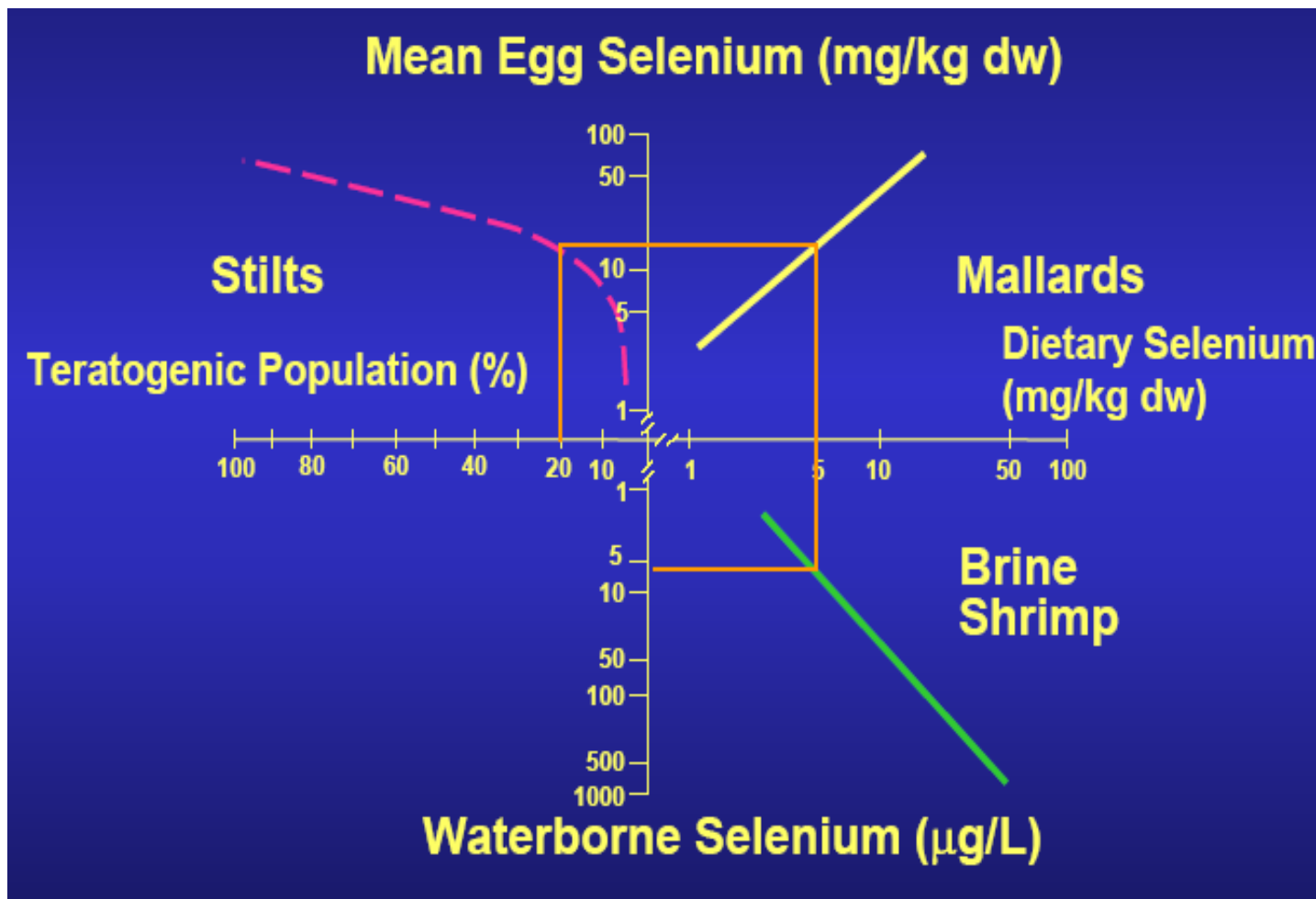


# Bird - Selenium Relationships

**⌘ Risk of reproductive effects can be estimated from selenium in:**

- ☒ Eggs (best predictor)**
- ☒ Diet**
- ☒ Water**
- ☒ Sediment (worst predictor)**

# Bird - Selenium Relationships



# Studies Planned or Underway

## ⌘ **Pupfish Evaluation for Imperial Valley Drains for Water Transfer Mitigation**

- ☒ Laboratory study to determine pupfish sensitivity to selenium
- ☒ Monitoring program to develop baseline for selenium in water, sediment, and biota in drains that discharge to Salton Sea